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Dielectric properties of sea water and aqueous solution

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Abstract : The dielectric properties of sea water samples and aqueous solution have been measured using *C*-Band microwave bench experimental setup. The dielectric properties are evaluated at room temperature and at 5-GHz frequency using Roberts and Von-Hipple technique. The dielectric properties of sea water samples are compared with the dielectric properties of pure water with the addition of aqueous NaCL solution. It has been observed that, the dielectric constant (ε') and dielectric loss (ε'') of sea water samples is different for different water samples It has been also observed that the values of ε' and ε'' of pure water varies with the addition of aqueous NaCl solution and they are approaching the experimental result for sea water.

Keywords : Dielectric properties , Sea water samples, *C*-band experimental setup

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The insight into molecular properties of water has a substantial influence on ecological, industrial and medicinal developments. This unique liquid plays a dominant role in many fields of scientific research. In the present paper, the measurements of dielectric properties of sea water samples and variation in dielectric properties of pure water with the addition of aqueous NaCl solution are recorded using 6 cm *C*-band microwave bench setup. The sea water samples are collected from Mumbai, Goa and Thiruvananthapuram beaches. The investigation of dielectric properties providing information about structural and dynamic properties of the material, it is very useful parameter to decide size and shape of the molecule. It also serves an important properties of the solution such as activity and conductivity. [1,2].

The experimental technique adopted for the measurements of dielectric properties of sea water samples and variation in dielectric properties of pure water with the addition of aqueous NaCl solution is that of Roberts and Von Hipple [3] and fixed frequency method of Gopal Krishna [4]. The dielectric constant and dielectric loss have been evaluated using least square fit technique of Sobhanadri [5].

For the meausurements of dielectric properties of the liquid samples, the experimental method has been modified by the authors [6] with the help of PC, stepper motor, lead screw, lock nut, and two electrical switches. The data has been acquired with the help of a mother board fixed in a PC. The liquid dielectric cell used in this experimental setup is also modified with the help of suitable mechanical coupling for moving the plunger in liquid column in liquid dielectric cell, with the help of stepper motor, and is used to measure the dielectric properties of liquid samples.

In experiment, the liquid dielectric cell is connected to the other end of the microwave bench setup with zero position of the plunger. The microwave source used in this frequency domain experimental technique is Avantek Varactor Tuned Oscillator (VTO, 8490). Firstly, energizing the microwave source the probe on the slotted line was moved along the slot line for perfect standing wave pattern, then the probe was fixed at the first minima nearest to the liquid dielectric cell. The liquid under test was filled into the liquid dielectric cell and the plunger of the liquid cell was moved by a fixed amount of 0.25 mm automatically with the help of stepper motor with suitable software written in quick basic. The number of points and the corresponding microwave current (power) can be saved on the memory, in a suitable format to be used with a least square fit programme developed for the purpose of power measurement. The power at the location of the plunger with zero position in concentrated solutions is given by the equation

$$P = P_0 \left[1 + \frac{(\gamma_2 - \gamma_1) \;\; \exp(2\gamma_1 d) + (\gamma_2 - \gamma_1)\, R}{(\gamma_2 + \gamma_1) \;\; \exp(2\gamma_1 d) + (\gamma_2 - \gamma_1)\, R_0} \right] \tag{1}$$

where $\gamma_2 = \alpha_2 + j\beta_2$ is the propagation constant in the waveguide section presiding the dielectric cell, $\gamma_1 = \alpha_1 + j\beta_1$ is the propagation constant in the dielectric cell. $R = R_0 \exp(j\phi)$ is the complex reflection coefficient of the plunger in contact with the dielectric. This eq. (1) was fitted in experimental data using α_1, β_1, ϕ and P_0 as fitting parameters. The value of β_2 $(2\pi/\lambda_g)$ was measured experimentally and R_0, α_2 are assumed to be one and zero for ideal plunger respectively.

Also in a suitable format to use a least square fit programme developed for the purpose, the power at the location of the plunger with zero position in dilute solution ($z = 0$), is given by the equation

$$P = EE^* = |P|^2 = P_0 \left[1 + e^{-4}\, \alpha_1 d + 2e^{-2} \alpha_1 d \cos(2\beta d_1 - \delta) \right]. \tag{2}$$

Here, E is the total amplitude of the resulting wave in the air medium and E^* is the complex conjugate of E.

This eq. (2) was used under two fitting conditions. In the first condition, α_1, β_1, P_0 and δ were used as fitting parameters and in second condition, δ is taken as π with α_1, β_1 and P_0 as fitting parameters. It was found that the better fit can be obtained with the help of first condition. The real and imaginary parts of the permittivity are :

$$\varepsilon^* = (\varepsilon' - j\,\varepsilon'').$$

They have been determined from the following equations

$$\varepsilon' = \lambda_0^2 \left[\frac{1}{\lambda_c^2} + \frac{\beta_1^2 - \alpha_1^2}{4\pi^2} \right] \tag{3}$$

and

$$\varepsilon'' = \frac{\lambda_0^2 \alpha_1 \beta_1}{2\pi^2}. \tag{4}$$

eqs. (3) and (4) are used to calculate dielectric constant and dielectric loss of the liquid samples [1].

The dielectric properties data *i.e.* the values of dielectric constant and dielectric loss of sea water samples are reported in Table 1. The variation in dielectric properties of pure water with the addition of aqueous NaCl solution are reported in Table 2.

Table 1. Dielectric study of sea water samples

Sr No.	Source of sea water	EPS (ε')	EPSP (ε'')
1	Thiruvananthapuram sea water	82 9	8.5
2	Mumbai sea water	79 4	11 3
3	Goa sea water	82 6	7 6

From Table 1, it is observed that the dielectric loss *i.e.* ionic conductivity of sea water samples is 93% larger than that of pure water (Table 2, zero concentration). The physical basis of high dielectric loss of the sea water samples is their high salinity. The dielectric loss is a parameter which describes the motion of the electric charge *i.e.* a conduction phenomenon. Certain dielectric are found to display conduction which arise not only from the effect of polarization on the displacement current, but actual charge transport *i.e.* ionic conduction in electrolytes. It has also been observed that the dielectric loss of Mumbai sea water is remarkably higher than that of pure water and it is also higher than Goa and Thiruvananthapuram sea water samples.

Table 2. Dielectric study of pure water with increasing concentration of aqueous NaCl solution

Salt	Conc. mole/liter	EPS (ε')	EPSP (ε'')
NaCl	0 0 (pure water)	80.8	0.7
	0 2	79 1	1.3
	0 4	79 3	1 5
	0.6	80 1	1.6
	0 8	79 6	1 8
	1.0	79 8	1 9

From Table 2, it is observed that for concentrations between 0.2 to 1.0 mole, the dielectric constant of water is smaller than that of pure water. The variation in dielectric constant with concentration observed for the above aqueous solution is found to be in accordance with earlier investigations of Sack [7] and Debye-Huckel [8]. Similar behavior of dielectric constant has been reported by Mehrotra *et al* [9] and Navarkhele *et al* [10].

From Table 2, it has also been observed that the dielectric loss of pure water increases continuously with increasing concentration of sodium chloride solution. This behavior is similar to $Ca(NO_3)_2.4H_2O$ in aqueous solution of urea [9], and also to the dielectric relaxation study of primary alcohol-water mixtures using TDR technique [11].

As reported in Table 2, zero concentration is nothing but the pure water. Comparing the dielectric constant of pure water with sea water samples, it has been observed that the dielectric constant of Mumbai sea water sample is lower and the dielectric constant of Goa and Thiruvananthapuram sea water samples is higher than that of the pure water. This variation in dielectric constant of sea water samples is due to the presence of high salinity or due to the presence of higher ionic conduction in electrolytes [6].

From Tables 1 and 2, it has been observed that the variation in dielectric properties of sea water samples are similar to that of variation in dielectric properties of pure water with the addition of aqueous NaCl solution, but this variation is small. The variation in dielectric properties will be more when aqueous solution of higher mole concentration is added to pure water, and they will approach the experimental result for sea water samples. Similar variation was obtained with the addition of another salt into pure water [6].

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References

[1] N E Hill, W E Vaughan, A H Price and M Davice *Dielectric Properties and Molecular Behaviour* (London : Von Nostrand-Reinhold) (1969)

[2] J B Hasted *Aqueous Dielectrics* (London : Chapmann and Hall) (1973)

[3] S Roberts and A Von Hipple, *J. Appl. Phys.* **17** 610 (1946)

[4] K V Gopal Krishna *Trans. Farad. Soc.* **53** 767 (1957)

[5] J Sobhanadri *Trans Farad. Soc.* **56** 340 (1960)

[6] V V Navarkhele, R S Agrawal and M L Kurtadikar *Pramana J. Phys* **51** 511 (1998)

[7] H Sack *Phys. Z.* **27** 206 (1926)

[8] P Debye and E Huckel *Phys. Z.* **29** 121, 401 (1928)

[9] S C Mehrotra, A C Kumbarkhane, S N Helambe and B R Arbad and D V Jahagirdar *Indian J Chem.* **33A** 878 (1996)

[10] V V Navarkhele, R S Agrawal and M L Kurtadikar "*Dielectric Properties of Rain Water In Microwave Region*" *J. Ecotoxicol Environ. Monit* (Palani, India : Palani Paramount Publication) **8** 97 (1998)

[11] S M Puranic, A C Kumbarkhane and S C Mehrotra *Proc. Nat. Acad. Sci.* (India) **63(A)** II 415 (1993)